Highly Accelerated Stress Screening of the Atlas Liquid Argon Calorimeter Front End Boards

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Abstract

It is anticipated that Highly Accelerated Stress Screening (HASS) will be performed as part of the quality assurance process for the Atlas liquid Argon calorimeter front end boards. This note describes the test setup and its capabilities, and reports on an initial series of tests performed from March 2nd to 5th, 2004.

1 Introduction

Accelerated testing has long been recognized by industry [1] as a very effective means of improving reliability and thus reducing costs of electronic components. In a high energy physics experiment, improved reliability translates into reduced need for hardware intervention (and detector access), leading to increased detector efficiency and stability.

Hass testing itself is achieved by rapid thermal cycling and broadband random vibrations, exposing both design and fabrication weaknesses. For the specific case of the liquid Argon calorimeter front end boards, the emphasis will be put on the early discovery of bad soldering joints and reduction of infant mortality due to fragile components. A more detailed description of the full series of tests proposed for the front end boards is the subject of a different note [2].

2 The HASS Test Setup

The HASS chamber is a large, insulated volume with a platform equipped with pneumatic hammers to induce vibrations (typically between 10 and 5000 Hz, and from 1 to 60 g). High-power heating elements and liquid nitrogen are used in combination with significant airflow to provide rapid temperature change in the chamber. The chamber used for the initial tests is a Qualmark HALT+HASS System OVS4 (figure 1), located at Algen Design Services [3] in New Jersey. A similar, if not the same chamber will be used during the production run.

The test setup itself consists of 1 front end crate located in the HASS chamber, and a PC and VME crate next to the chamber used for controls and readout. Since the front end boards do not have cooling plates at this stage (the preamps are not mounted yet), the backplane of the front end crate has been removed to allow sufficient airflow to cool the boards. The front end boards to be tested, as well as a custom clock fanout board are inserted in every second slot in the crate, leaving the other slots open, again to allow ample airflow for cooling. The power, optical and spac cables are routed through a window in the side of the HASS chamber to a power supply and a 6U VME crate, as can be seen in figure 3. The crate contains a spacmaster,

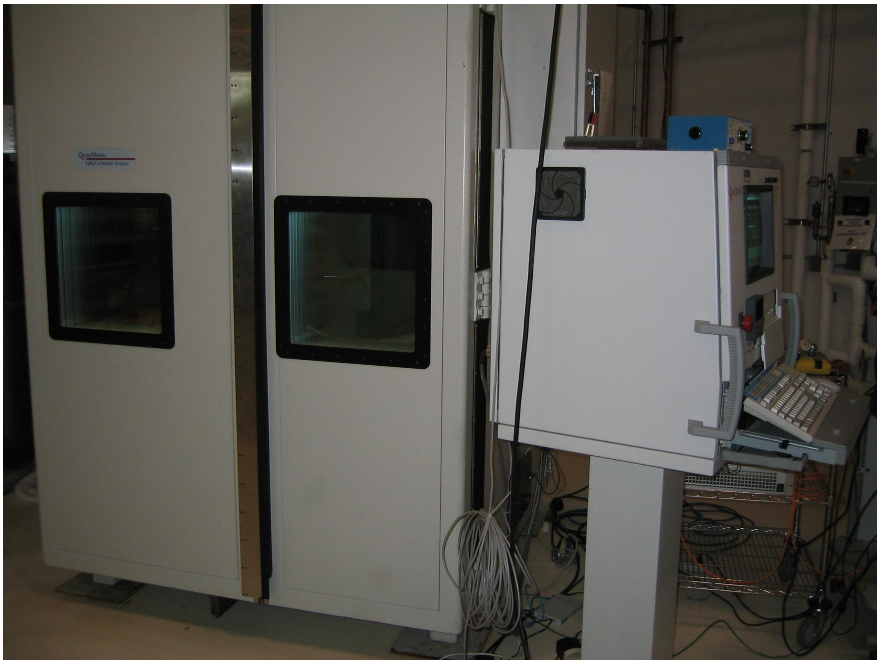

Figure 1: The Hass test chamber.

a TTCVI, a TTCVX and one or more mini-RODs developed and built at Nevis, and is interfaced to a PC using a bit3-type module with optical link to a PC. Figure 2 is a schematic representation of the setup.

3 Initial Tests

During the period of March 2nd-5th 2004 the test setup and two pre-production front end boards were subjected to a series of tests with the goals of a) having the boards undergo a large number of temperature ramps, b) accumulating more time at high and low temperature than expected in production and c) determining the breaking point of the boards.

One of the two boards (serial # 138353) was equipped with preamplifiers while the other (serial # 138354) wasn't. The crate with the two boards and the clock fanout board can be seen inside the HASS chamber in figure 4.

The first three days were dedicated to temperature tests: with initial extrema set at 55 and 0 °C, the chamber was ramped to one setpoint at a ramping rate of 10 °C per minute, then maintained at that temperature for 15-60 minutes before ramping to the other setpoint. A so-called digital test, used to measure pedestals and noise, was performed at regular intervals to verify board performance. Voltages and temperatures were measured through the on-board DCU chips every 60 seconds, and the strength of the optical output signal was measured every few hours. 33 ramps to 55 °C, most of which started at 0 °C were made, leading to an integrated time at $T \geq 45\,^\circ$C of 11.8 hours. There were 26 ramps down to 0 °C, with a total time of 5.5. hours spent at $T \leq 10\,^\circ$C. Figure 5 shows the temperature measured on one of the boards for the full duration of the tests. The only deterioration in performance observed was an increase in noise in 10 channels for the board equipped with preamps, but this only manifested itself after 5-10 minutes at 55 °C and disappeared when the board was brought back to room temperature. This is illustrated in figure 6.

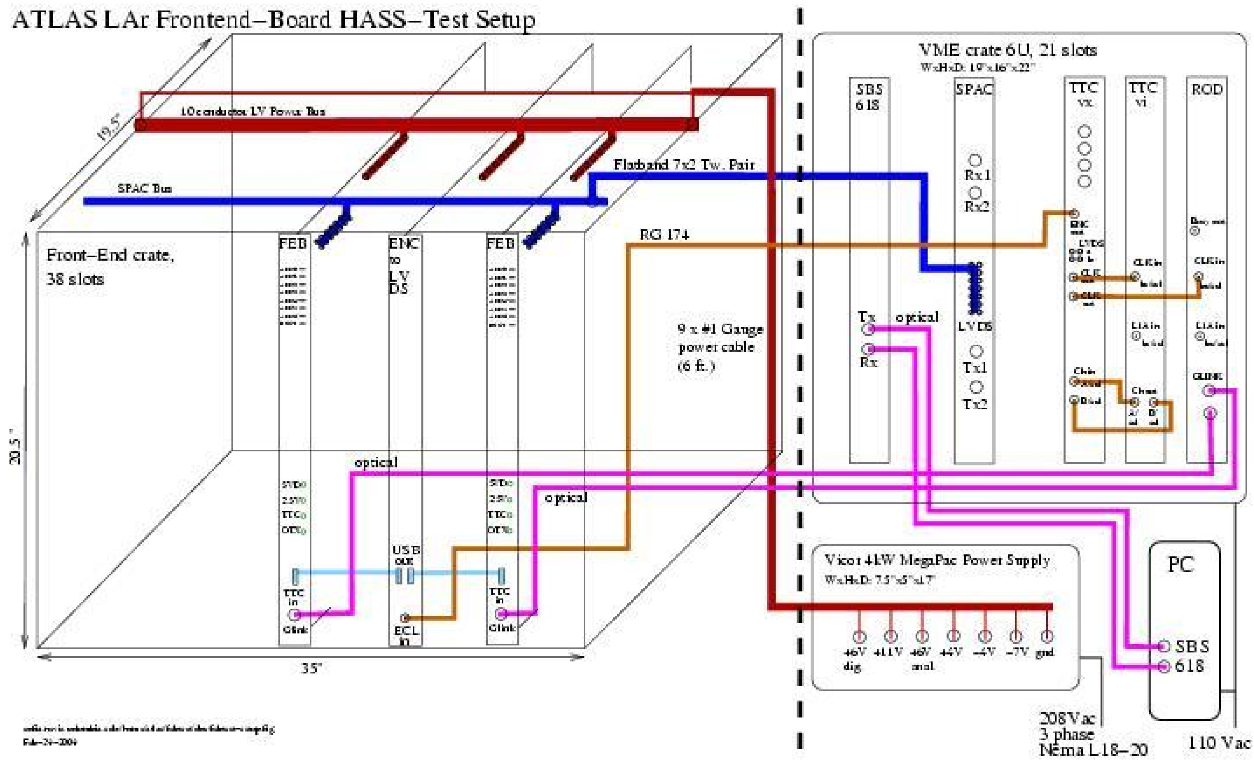

Figure 2: Schematic diagram of the Hass test setup for the front end boards. The vertical dashed line separates the components located inside the HASS chamber (on the left) from those outside.

Figure 3: The power supply, 6U VME crate and PC used in the HASS test setup.

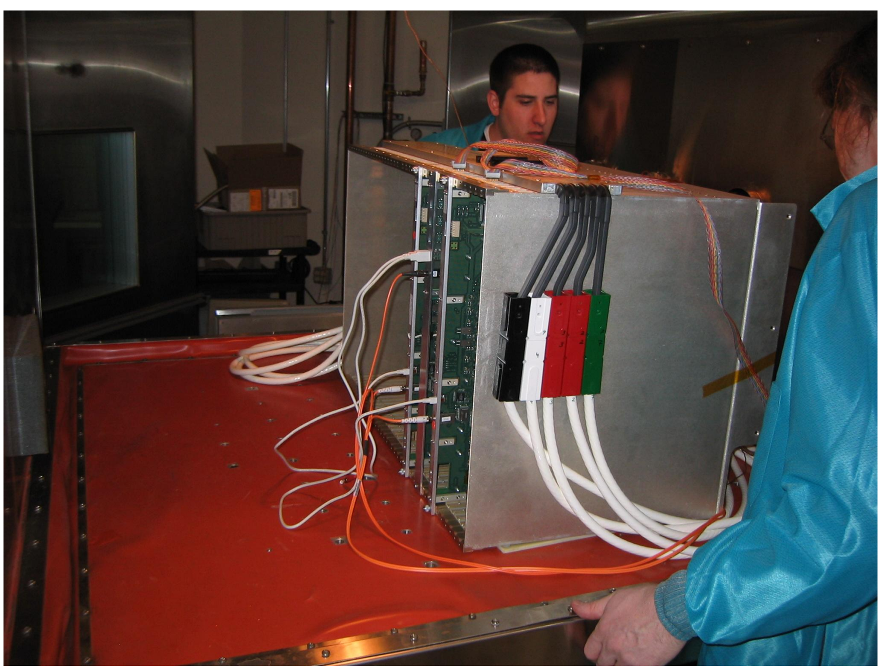

Figure 4: The front end crate with the two boards used for the initial tests inside the HASS chamber.

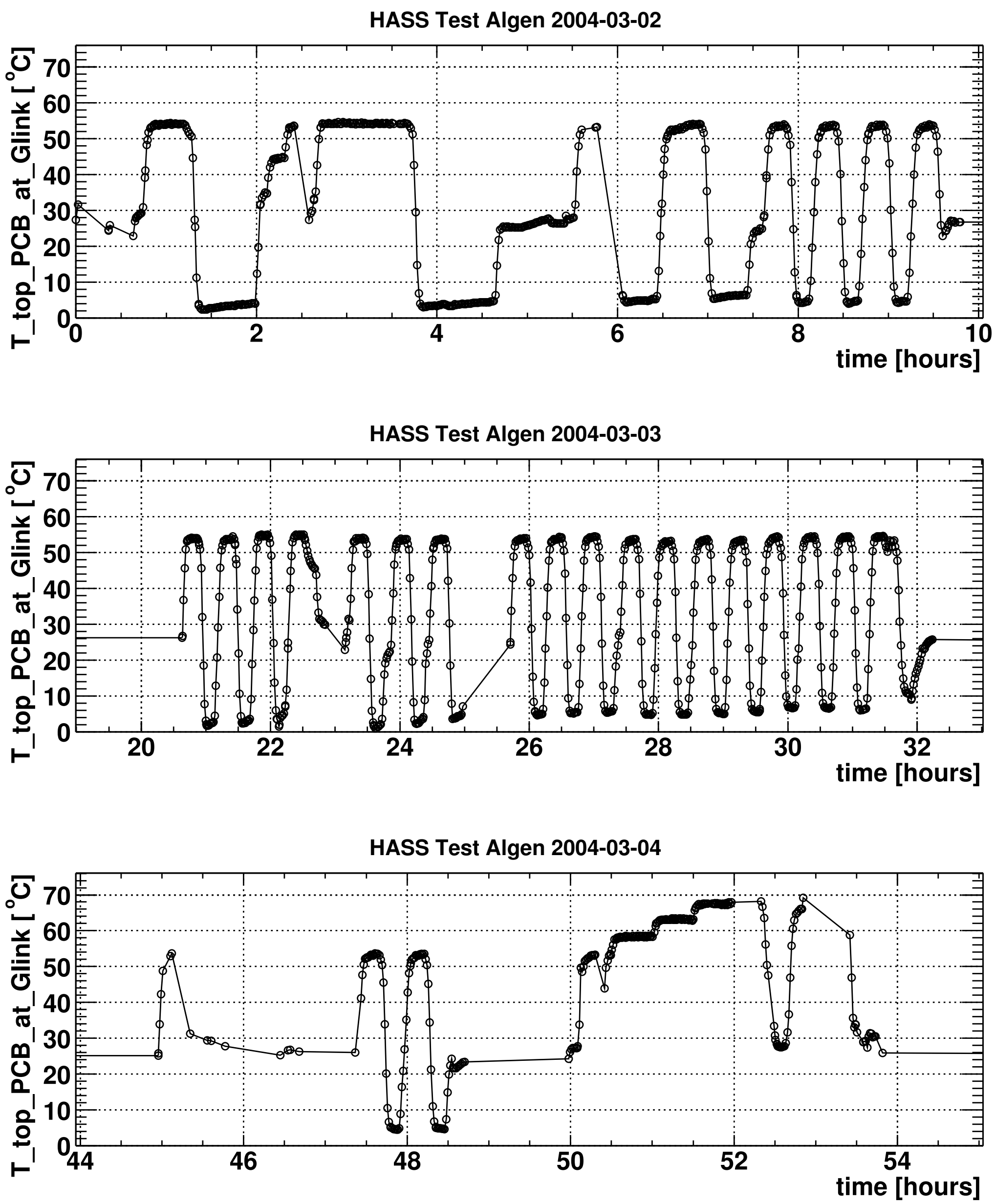

Figure 5: Temperature measured on one of the boards as a function of time in the test for each of the three days dedicated to environmental testing.

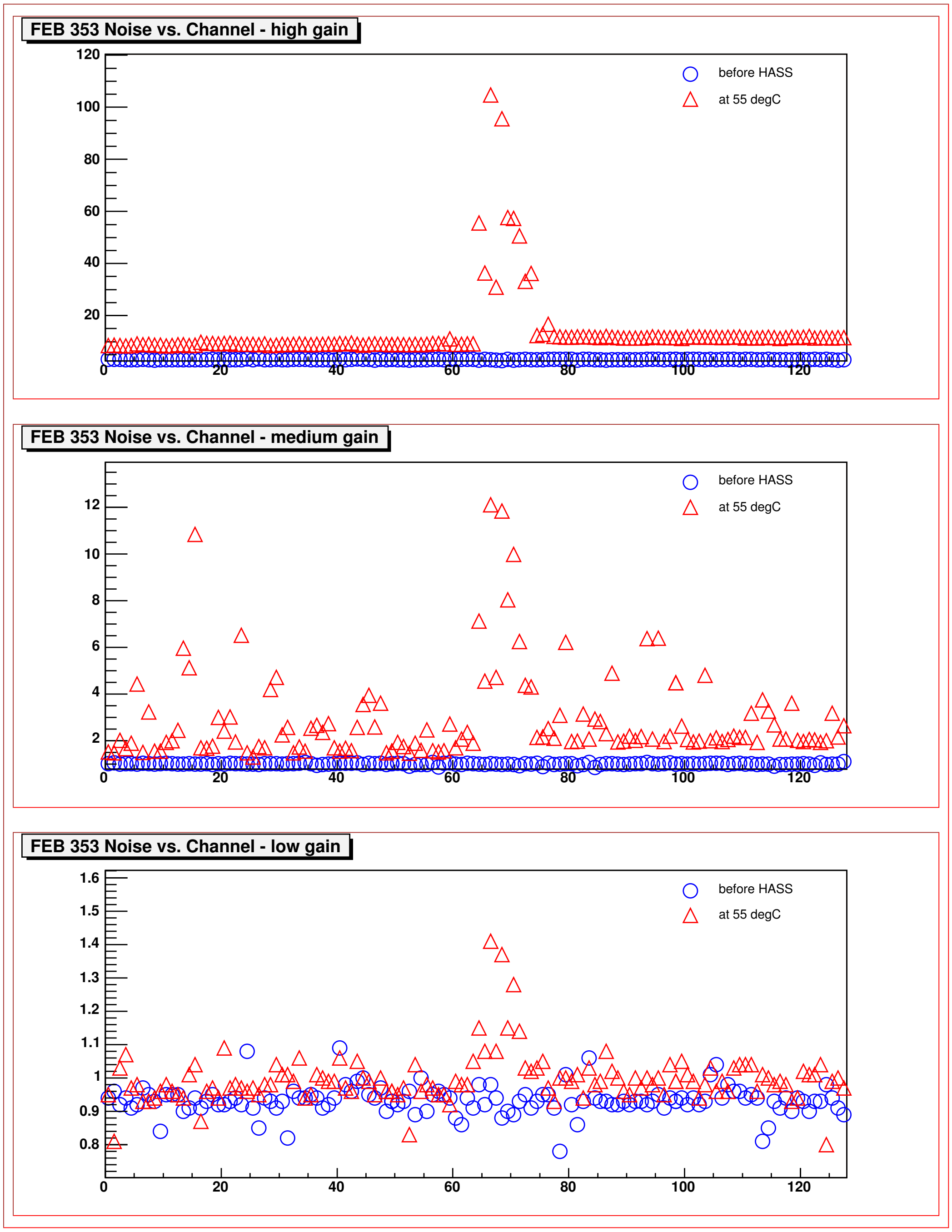

Figure 6: Comparison of noise levels at room temperature and 55 °C for FEB 138353.

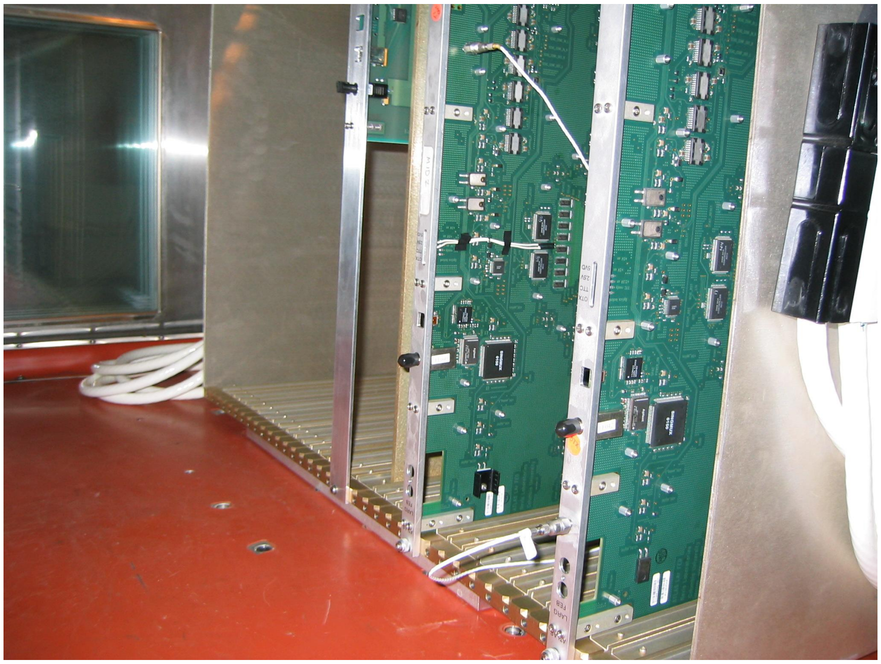

Figure 7: Image of the two front end boards used in the HASS initial tests with accelerometers glued to the boards (on the lower part of the front panel for the right-hand board, on the PCB for the left-hand board).

After this series of tests was completed, the temperature was driven up gradually to estimate at which points the board breaks down, and which one of the components is most sensitive to elevated temperatures. The temperature was increased in steps of 5 °C, and maintained at a given level for approximately 30 minutes before being brought down to room temperature to verify that no permanent increase in noise had been induced. Just below 75 °C communication with the boards became impossible (both through the SPAC and the optical readout), but when the boards were cooled down after 30 minutes at 75 °C, no change in performance was observed. After an additional heating period of 30 minutes at 80 °C however, one of the two boards could not be read out through the optical link. The measured light output for this transmitter had not changed (-7 dBm, as before the heating cycles). However, the modulation signal was not observable anymore and after replacing this component, the board behaved as before again.

The final day was dedicated to vibration tests. As opposed to the environmental tests during which the boards were powered and read out at regular intervals, for the vibration tests the boards were not powered or read out. This was motivated by two main concerns: the optical connectors, which use a spring-like system to ensure optical contact, were likely to get damaged, and the SPAC bus connectors appeared rather fragile. Damaging the board-side of the optical connectors would prevent us from learning anything more, and we had no spare SPAC connectors. Of course, after every period of vibrations (typically 15 minutes), the boards would be submitted to a full test.

Initially, the front end crate was used as a fixture for the boards, but accelerometers glued to the boards (see figure 7) indicated that due to the crate's structure and relatively large mass vibrations were transmitted rather poorly to the boards themselves. The tests performed in this configuration had accelerations of up to 30 g for the HASS platform, but the accelerations measured on the boards never exceeded $\approx 4g$.

A second series of vibration tests was then performed in which the boards were fastened to the HASS chamber's platform using a dedicated fixture which allowed for nearly 100% transmission of the acceleration

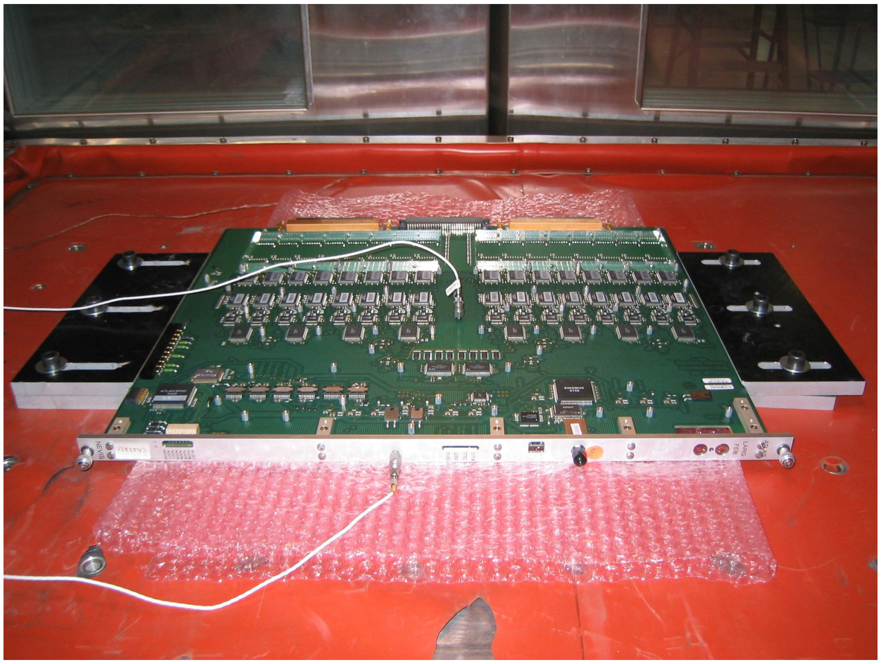

Figure 8: A front end board in a dedicated fixture allowing increased transmission of the vibrations to the board.

to the board. This is shown in figure 8. Vibration intensity was increased gradually, initially in steps of 5 g, later in steps of 10 g. After 15 minutes, the board was taken out and tested while the other board was submitted to vibrations. Even after vibration at 55 g, the chamber's limit, no effect was observed on the board performance.

The intensity of the optical transmitter outputs was measured regularly during the full period of temperature and vibration tests and was found to be stable at -6 dBm and -7 dBm for the two boards, respectively.

4 Comparison of Pre- and Post-Test Performance

Since the crate used for the HASS testing had no backplane, only the so-called digital test could be performed at that time. Therefore, in addition to these, the boards were tested in a more complete setup at Nevis. The latter uses a crate with a backplane, has capacitive loads and allows the injection of signal through a DAC.

Figures 9 and 10 are the distributions that are also available in the digital test: the pedestals and noise for each channel at each gain setting. No measurable change can be seen. The measurement of the coherent noise is sensitive to the conditions, and in figure 11 it can be observed to appear smaller after the HASS test than before. While this is probably due to slightly different grounding conditions rather than actual improvement of the board, it does suggest that the coherent noise on the boards has not deteriorated. Finally, figure 12 suggests a deterioration in the energy resolution of up to 20-25% for the worst channels. Further investigation is required to determine the source of this degradation. Note that the odd behavior in channels 64 to 127 is due to the calibration board used at Nevis and not the FEB.

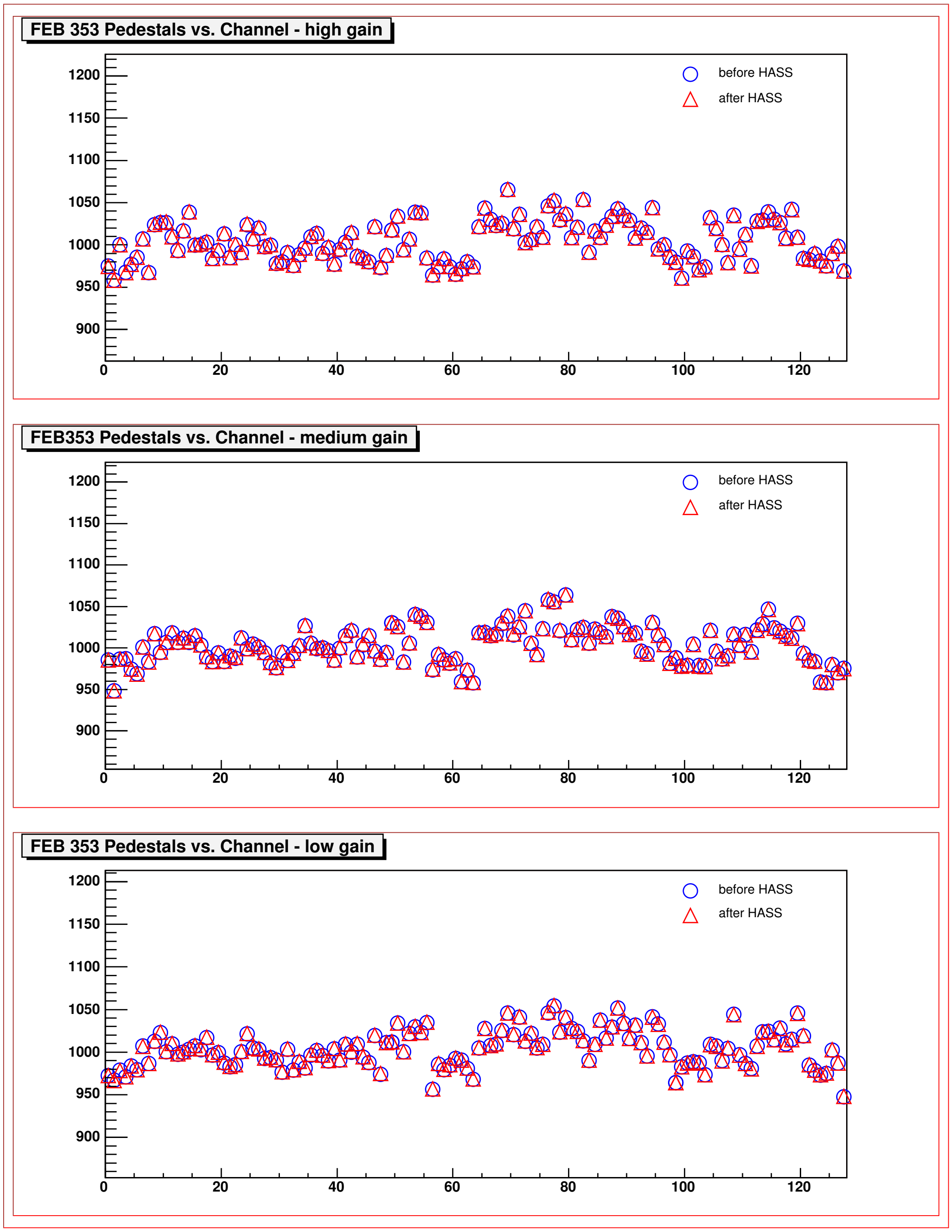

Figure 9: Comparison of the pedestals for all three gains on FEB 138353 before and after the HASS test. No difference is observed.

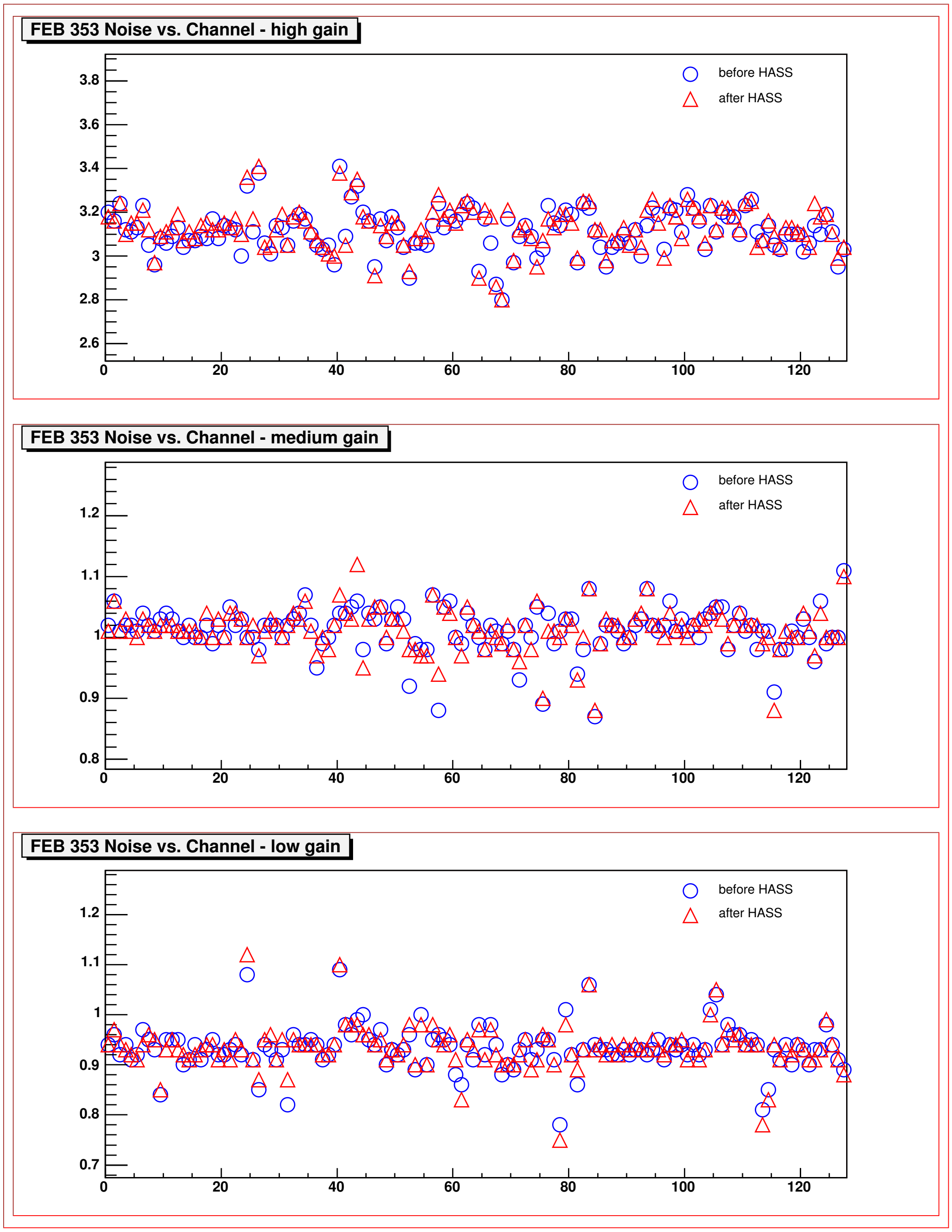

Figure 10: Comparison of the noise for all three gains on FEB 138353 before and after the HASS test. No difference is observed.

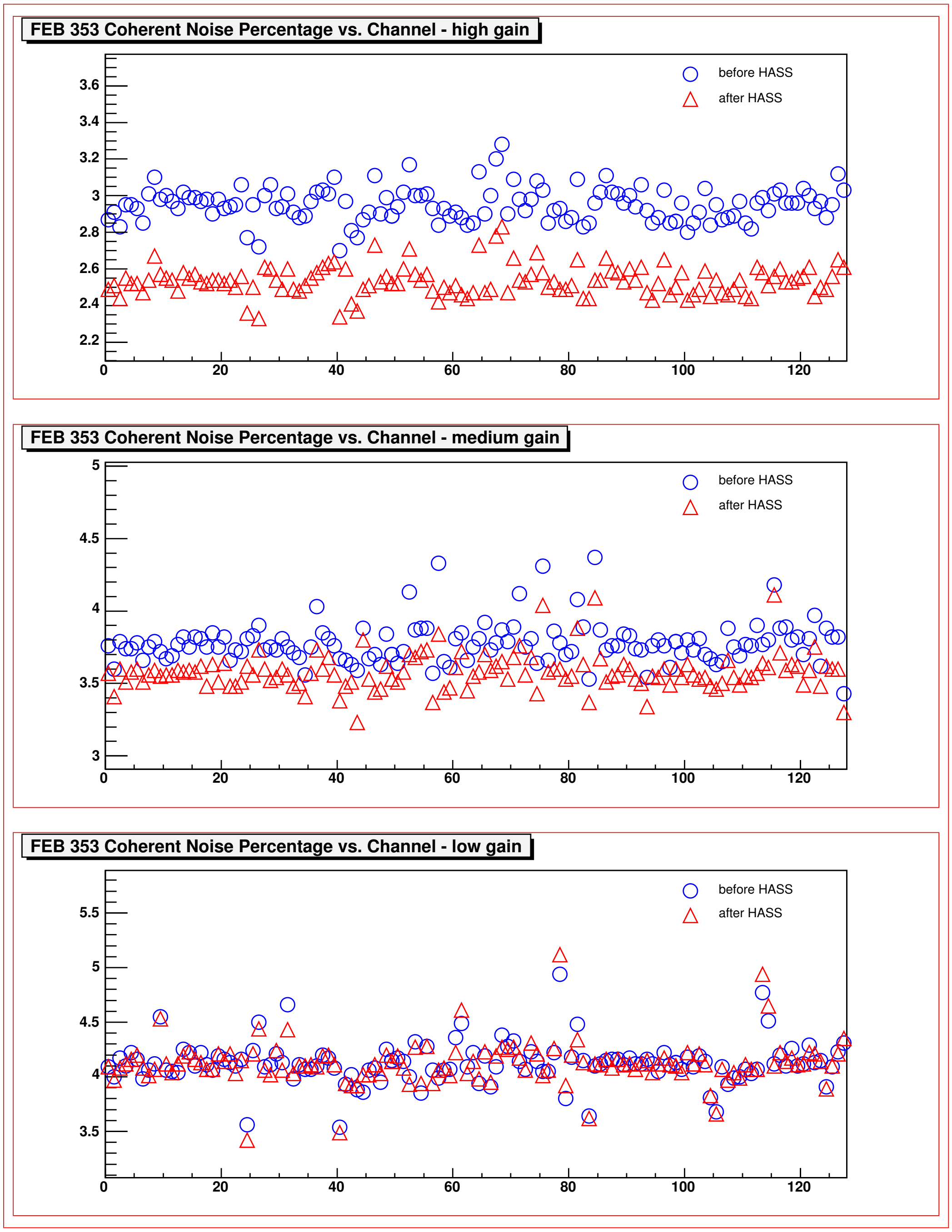

Figure 11: Comparison of the coherent noise for all three gains on FEB 138353 before and after the HASS test. The coherent noise is given as percentage of the total noise.

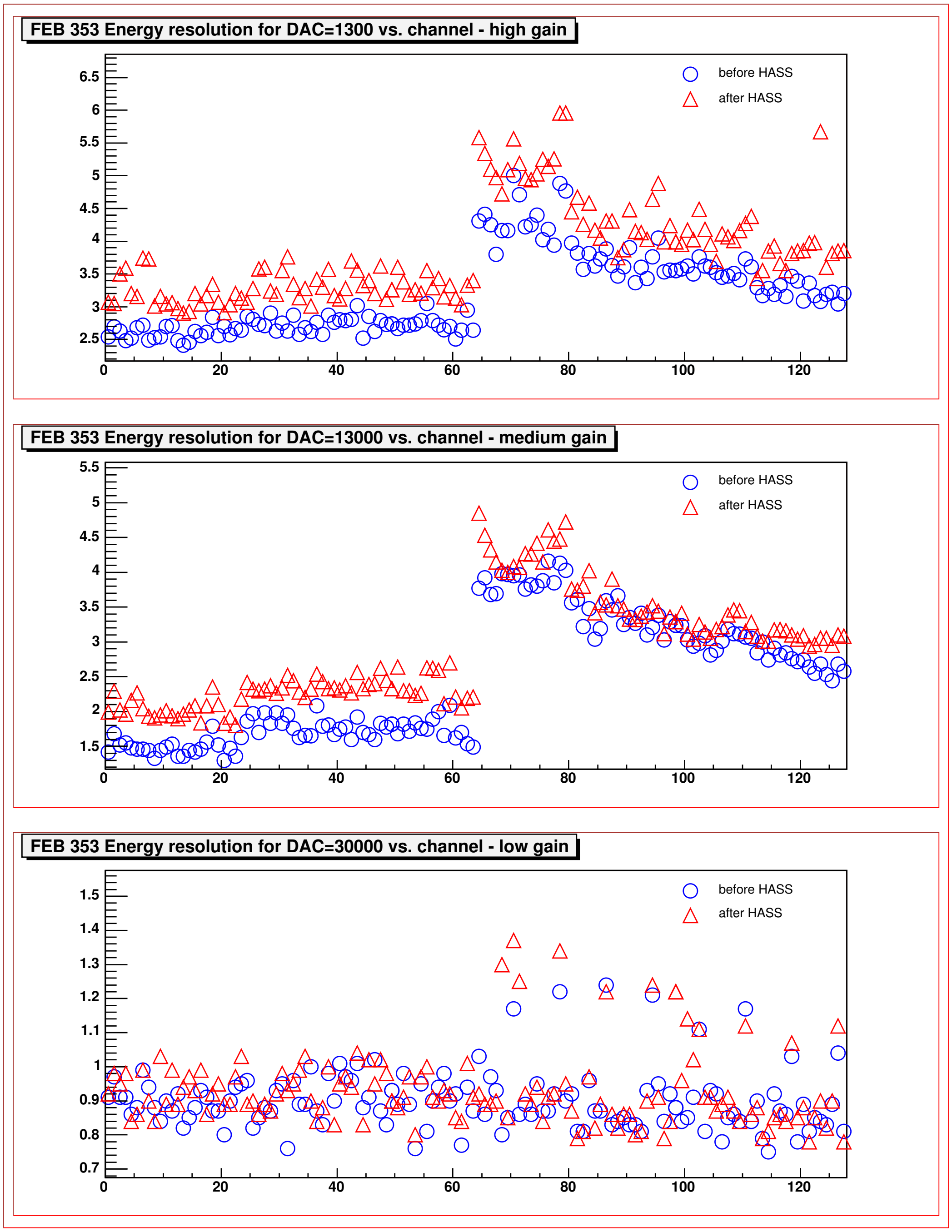

Figure 12: Comparison of the energy resolution for specific DAC settings for FEB 138353 before and after the HASS test.

5 Conclusions

During production, the Atlas liquid Argon calorimeter front end boards will be subjected to Highly Accelerated Stress Screening (HASS) to detect fabrication faults at an early stage. Two preproduction boards have been subjected to a series of stress tests that were both longer and more intensive than the proposed tests for production boards. They have performed remarkably well and the only component failure observed happened at an operating temperature which was beyond the component's specified range of operability. It has been established that good boards can endure these tests without significant degradation in performance. These results suggest that HASS testing can be used safely to detect bad FEBs at a very early stage.

References

[1] See for example http://shop.ieee.org/store/product.asp?prodno=HV7061.

[2] http://www.nevis.columbia.edu/ atlas/electronics/ATLASFEB/FEBtesting_v1.5.pdf.

[3] http://www.algendesign.com/.